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THE DATA MINING: AN ANALYSIS OF 20 ECLIPSING BINARY LIGHT-CURVES OBSERVED BY THE INTEGRAL/OMC

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ABSTRACT

Twenty eclipsing binaries were selected for an analysis from a huge database of observations made by the INTEGRAL/OMC camera. The photometric data were processed and analyzed, resulting in a first light-curve study of these neglected eclipsing binaries. Most of the selected systems are the detached ones. The system ET Vel was discovered to be an eccentric one. Due to missing spectroscopic study of these stars, further detailed analyses are still needed.

Keywords: stars: binaries: eclipsing – stars: individual: ZZ Cas, BG Cas, EN Cas, GT Cas, IL Cas, V435 Cas, CM Cep, DP Cep, SZ Cru, AY Cru, GG Cyg, V466 Cyg, V809 Cyg, Z Nor, V1001 Oph, V986 Sgr, BY Vel, CZ Vel, DF Vel, ET Vel – stars: fundamental parameters

1. INTRODUCTION

The INTEGRAL (INTErnational Gamma-Ray Astrophysics Laboratory) satellite was launched on 17 October 2002. Since then, there were many observations of the gamma-ray and X-ray sources obtained. Thanks to the OMC (Optical Monitoring Camera), there was collected also a large database of the photometric observations in the visual passband. The variable stars observations were obtained as a by-product.

A huge database of all observations obtained by OMC is freely available on internet, but the analyses are still very rare. The present paper is following a similar study of three selected Algol-type binaries PV Cyg, V822 Cyg, and V1011 Cyg, see Zasche (2008). The selection criteria used here were the following: Maximum number of data points and non-existence of any light-curve analysis of the particular system. There were 20 systems selected for the present paper.

2. ANALYSIS OF THE INDIVIDUAL SYSTEMS

All observations of these systems were carried out by the same instrument (50mm OMC telescope) and the same filter (Johnson's V filter). Time span of the observations ranges from November 2002 to July 2006. A transformation of the time scale has been done following the equation $JulianDate - ISDCJulianDate = 2,451,544.5$. Only a few outliers from each data set were excluded. The Phoebe programme (see e.g. Prša & Zwitter 2005), based on the Wilson-Devinney algorithm (Wilson & Devinney 1971), was used.

Due to missing information about the stars, and having only the light curves in one filter, some of the parameters have to be fixed. At first, the "Detached binary" mode was used for computing (except for V435 Cas). The limb-darkening coefficients were interpolated from van Hamme's tables (see van Hamme 1993), the linear cosine law was used. The values of the gravity brightening and bolometric albedo coefficients were set at their suggested values for convective atmospheres (see Lucy 1968), i.e. $G_1 = G_2 = 0.32$, $A_1 = A_2 = 0.5$. In all cases (except for ET Vel) the orbital eccentricity was set to 0 (circular orbit). Therefore, the quantities which could be directly calculated from the light curve are the following: The luminosity ratio L_1/L_2, the temperature ratio T_1/T_2, the inclination i, ephemerides of the system, the Kopal's modified potentials Ω_1 and Ω_2, the synchronicity parameters F_1 and F_2, the third light l_3, and the mass ratio q. Because we deal with the detached systems, the last quantity was derived via a "q-search method", which means trying to find the best fit with different values of q ranging from 0 to 1 with a step 0.1 (all systems except for V466 Cyg range in these limits). Using the parameters introduced above, one could also derive the value of the radii ratio R_1/R_2.

The distinguishing between the minima has been done only according to the observational point of view, which means that the deeper one is the primary one. This results in a fact that the primary component could be neither the larger one, nor the more massive one. In a few cases the secondary components result to be the more luminous ones, and in one case (V466 Cyg) also the more massive one.

All of the basic information about the analyzed systems are introduced in Table 1, where are the magnitudes from the GCVS (Kukarkin et al. 1971) compared with the actual OMC magnitudes in Johnson's V filter, the depths of both primary and also secondary minima in V filter, the orbital periods and also the $B-V$ indices (mostly taken from the NOMAD catalogue, Zacharias et al. (2004), which contains the most complete B and V observations of these stars). The spectral types were taken from various sources (see SIMBAD database).

The results are introduced in Fig.1 and Table 2, where are given all relevant parameters of the analyzed systems. Inclinations smaller than 90° mean that the binary rotates counter-clockwise as projected onto a plane of sky. Only one system (DF Vel) has its orbital period shorter than 1 day, V435 Cas is the only semi-detached system, and ET Vel was found to be the eccentric eclipsing binary. Its parameters are the following: the eccentricity $e = 0.0737$ and the argument of periastron $\omega = 1.067$ rad.

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TABLE 1
BASIC INFORMATION ABOUT THE ANALYZED SYSTEMS.

Star	Mag_{GCVS}	Mag_{OMC}	Mag_{MinI}	Mag_{MinII}	Period (d)	$B-V$	Sp.
ZZ Cas	10.80	10.87	11.49	11.19	1.2435	0.43	B3
BG Cas	12.90	12.79	13.68	12.90	3.9537	0.23	
EN Cas	12.30	11.39	12.22	11.66	4.4378	0.47	
GT Cas	11.90	11.55	12.37	11.59	2.9899	0.29	A0
IL Cas	11.50	11.09	11.71	11.18	3.4517	0.19	B5
V435 Cas	15.00	13.85	15.06	14.19	4.1561	0.90	
CM Cep	12.10	11.88	14.07	12.02	1.8589	0.36	B8
DP Cep	12.60	12.86	14.13	13.12	1.2700	0.22	
SZ Cru	10.90	11.49	12.45	11.58	1.9743	0.25	
AY Cru	11.10	11.28	12.24	11.38	1.5984	0.37	
GG Cyg	12.10	11.93	12.81	12.08	2.0084	0.38	A4
V466 Cyg	10.80	10.56	11.30	11.16	1.3916	0.40	A8
V809 Cyg	13.30	13.10	13.85	13.53	1.9645	0.11	F9
Z Nor	9.30	9.15	10.09	9.47	2.5569	0.15	B3IV
V1001 Oph	14.40	13.97	15.40	14.20	1.7894	0.96	
V986 Sgr	13.00	12.61	13.81	12.72	10.4297	0.58	
BY Vel	10.60	11.01	12.11	11.09	3.4553	0.50	
CZ Vel	10.80	10.83	11.50	11.05	5.1927	0.50	
DF Vel	13.30	13.33	15.11	13.64	0.7645	0.48	
ET Vel	11.90	11.14	11.76	11.75	3.0809	0.50	A0

In this system the temperature of the primary component (and also its luminosity) is lower than temperature of the secondary one, we can therefore doubt about the role of the two components. Moreover, both primary and secondary minima have approximately equal depths, so the primary and secondary components are probably interchanged.

Another interesting fact of this sample are the relative radii of these stars. In about one half of the systems the secondary components are greater than the primaries. Concerning the luminosities, there are also 5 cases where the third light (from the unseen component) has a statistically significant value above 5%. One could speculate about a prospective future discovery of such components in these systems. Due to missing detailed analysis (spectroscopic, interferometric, etc.), the only possible way how to discover these bodies nowadays is the period analysis of their times of minima variations. In the system ZZ Cas such an analysis exists and the third body was discovered, see Kreiner & Tremko (1991).

3. DISCUSSION AND CONCLUSIONS

The light-curve analyses of twenty selected systems have been carried out. Using the light curves observed by the INTEGRAL satellite, one can estimate the basic physical parameters of these systems. Despite this fact, the parameters are still only the preliminary ones, affected by relatively large errors and some of the relevant parameters were fixed at their suggested values. The detailed analysis is still needed, especially in different filters. Together with a prospective radial-velocity study, the final picture of these systems could be done. Particularly, the system ET Vel seems to be the most interesting one due to its eccentric orbit.

4. ACKNOWLEDGMENTS

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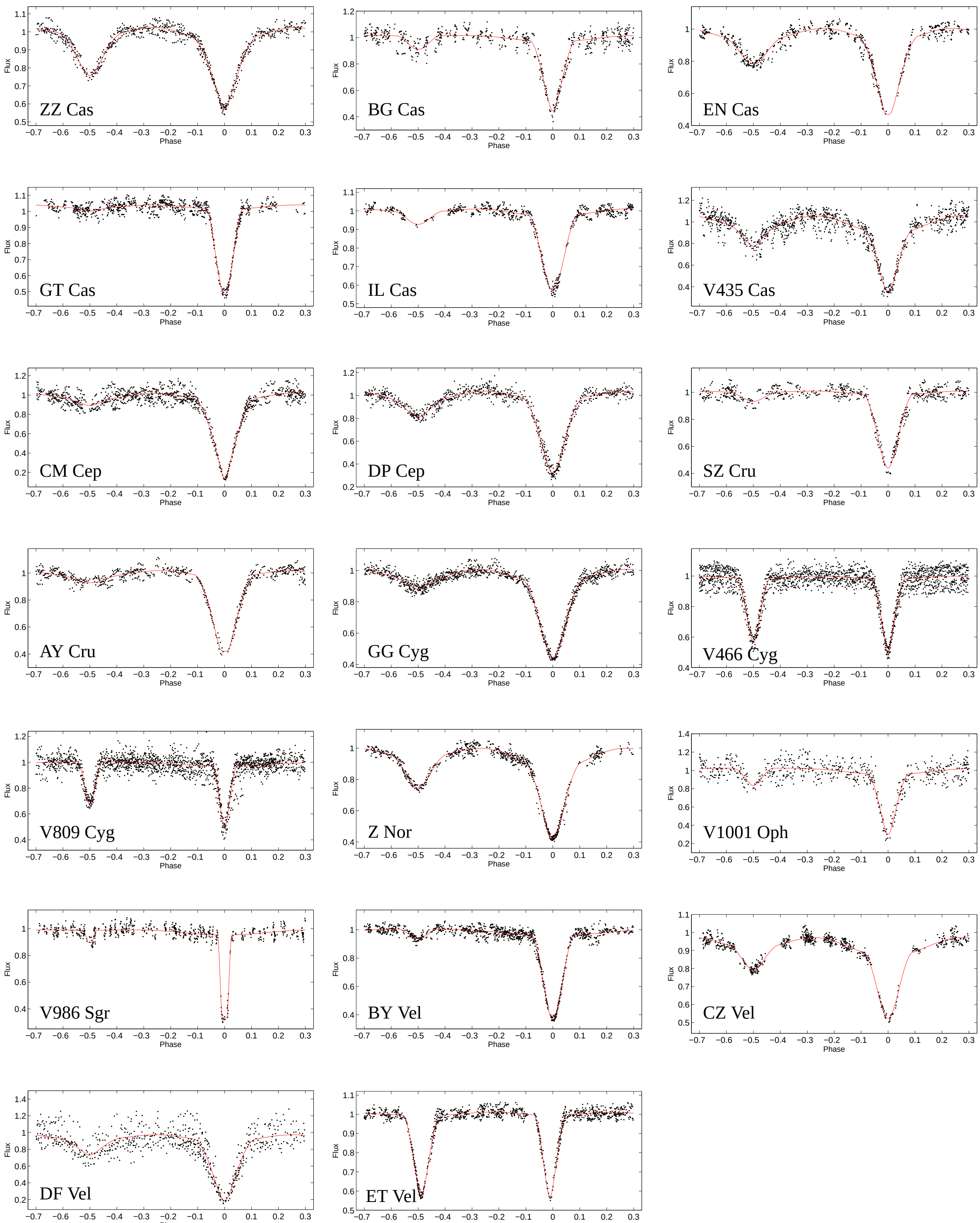
TABLE 2
THE LIGHT-CURVE PARAMETERS OF THE INDIVIDUAL SYSTEMS.

Parameter Star	HJD_0 2452000+	P [days]	i [deg]	q $= M_2/M_1$	Ω_1	Ω_2	T_1/T_2	L_1 [%]	L_2 [%]	L_3 [%]	R_1/R_2	F_1	F_2	x_1	x_2
ZZ Cas	637.564	1.24349377	86.552	0.7	3.664	3.583	1.49	55.0	21.4	23.6	1.17	1.439	1.560	0.287	0.367
BG Cas	655.132	3.95367825	96.126	0.5	4.153	3.926	2.02	86.4	6.3	7.3	1.32	1.400	3.496	0.412	0.718
EN Cas	657.014	4.43777896	86.727	0.6	3.492	3.613	1.07	80.5	15.5	4.0	1.33	1.159	2.082	0.612	0.668
GT Cas	641.291	2.98985074	78.687	0.2	6.143	2.141	2.54	81.0	7.0	12.0	0.66	5.155	0.000	0.248	0.422
IL Cas	639.814	3.45171726	75.645	0.6	4.224	3.195	1.43	80.2	11.2	8.6	0.92	0.414	0.000	0.504	0.488
V435 Cas	656.806	4.15607055	81.598	0.6	6.060	3.187	1.46	64.7	31.7	3.6	0.68	5.458	1.242	0.852	0.500
CM Cep	654.610	1.85892148	90.305	0.4	3.873	2.650	1.65	93.0	5.4	1.6	1.04	2.599	1.008	0.507	0.852
DP Cep	655.170	1.26999723	83.405	0.7	4.122	3.283	1.22	75.7	19.3	5.0	0.90	1.715	1.028	0.732	0.828
SZ Cru	702.564	1.97430610	82.118	0.6	4.150	3.534	2.32	89.6	6.7	3.7	1.09	0.889	0.925	0.087	0.276
AY Cru	702.551	1.59841897	90.944	0.4	3.154	2.780	1.27	95.6	4.1	0.3	1.34	0.810	0.818	0.458	0.527
GG Cyg	595.973	2.00837615	76.705	0.2	3.204	2.084	2.83	76.0	7.0	17.0	1.19	1.505	0.484	0.285	0.530
V466 Cyg	595.223	1.39156321	89.365	1.1	6.106	7.060	1.09	58.8	40.6	0.6	1.13	1.923	0.000	0.523	0.575
V809 Cyg	596.231	1.96445344	92.850	0.6	8.095	5.959	1.73	59.0	38.6	2.4	1.01	5.888	6.292	0.425	0.629
Z Nor	669.153	2.55694871	81.435	0.7	4.130	3.818	1.47	73.1	23.2	3.7	1.06	1.861	2.188	0.818	0.500
V1001 Oph	787.850	1.78942143	86.958	0.6	5.049	4.238	1.85	78.3	19.4	2.3	0.99	0.000	3.541	0.611	0.500
V986 Sgr	730.524	10.42963578	87.746	0.4	22.835	5.341	1.94	33.7	64.8	1.5	0.39	0.210	8.807	1.000	0.500
BY Vel	650.590	3.45533443	80.704	0.4	5.308	2.817	2.61	88.0	8.8	3.2	0.80	3.514	0.968	0.274	0.504
CZ Vel	651.500	5.19274753	79.017	0.4	4.604	2.822	1.35	76.0	23.9	0.1	0.94	3.376	1.426	0.500	0.500
DF Vel	650.762	0.76447904	87.432	0.9	4.154	3.691	1.28	78.4	21.4	0.2	0.89	0.579	0.691	0.751	0.657
ET Vel	749.273	3.08087500	86.663	0.9	6.131	5.615	0.96	47.4	51.6	1.0	0.97	1.032	1.000	0.680	0.646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